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10 August 1955

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Dear Dick:

We are forwarding herewith five copies of Informal Monthly Progress Report No. 1 covering the work performed on System No. 2 during the period extending from 13 June 1955 to 10 July 1955.

Sincerely,

Burt

Burt

Enclosure:

CMCC Doc. No. 163.2008,
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Martin

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Informal Monthly Progress Report No. 1

for the period

13 June 1955 to 10 July 1955

System No. 2

Contract No. A-101

CMCC Document No. 163, 2008

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Figure 2	Field-Equipment, Block Diagram

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1-0. GENERAL. The navigation phase of System No. 2, as proposed by the Contractor, provided for the determination of the azimuth and the true ground range of suitably equipped aircraft by means of measurements made at a single ground station. The Contractor proposed that these quantities be determined by a time measurement and two angle measurements; the time measurement to be a measurement of the time elapsed between sending r-f pulses to the aircraft and receiving r-f pulses from the aircraft; the angle measurements to be measurements of the average azimuth and elevation angles-of-arrival of r-f pulse trains transmitted from the aircraft.

2-0. OBJECTIVES. The principal effort during the period covered by this report was devoted to devising, preparing and conducting propagation experiments designed to determine whether or not the technique proposed for measuring average azimuth and elevation angles-of-arrival could provide data of sufficient stability and accuracy to meet the stability and accuracy requirements of the navigation system. Basically, the transmitting and receiving equipments devised for these experiments were designed to provide a measurement of the phase difference between the signals generated on separate antennas by the same transmitted signal; the object being to determine the extent of change of this phase difference as ionospheric signal-propagation paths and modes changed. The equipments devised to conduct these experiments and the results of the experiments are described in the following paragraphs.

3-0. INSTRUMENTATION.

3-1. The instrumentation used to determine the accuracy of the method proposed for measuring angles-of-arrival consisted of a portable field transmitting equipment situated at Trinidad, Colorado, and a receiving-station equipment situated at the Contractor's laboratory in Los Angeles. At the receiving site, azimuth angle-of-arrival was measured by means of two antennas located on a line drawn perpendicular to the direction of arrival, while elevation angle-of-arrival was measured by means of two antennas located on a line drawn parallel to the direction of arrival.

3-2. The field equipment devised for the experiments was a portable transmitting station which provided about 125 watts of r-f power on one of three high-frequency bands to a 36-foot vertical whip antenna. Both cw and repetitive pulsed transmissions were provided for; the pulsed transmissions having been provided to permit observation of the effects of multipath propagation on the accuracy and stability of angle-of-arrival measurements.

3-3. (See figure 1.) The pulse-timing circuits of the field equipment were controlled by a stable 400-cycle tuning-fork oscillator which drove a variable pulse-width, monostable multivibrator to provide output gate pulses of 80-microseconds, 160-microseconds, 320-microseconds, or 750-microseconds duration to the gating circuit. The r-f circuits of the field equipment included a one-megacycle crystal oscillator, the output of which was modulated by the gating circuit. The gated one-megacycle signal was combined in the mixer

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circuit with the output of the high-frequency oscillator. The three frequencies available in the crystal-controlled high-frequency oscillator were exactly one megacycle below the desired output frequencies. The sum frequency from the mixer was delivered to a voltage amplifier and driver which excited the power amplifier. The power amplifier used a single-ended Class "C" stage (a 4X150A tube) which coupled to the base-driven 36-foot, aluminum, vertical whip antenna by a pi-matching network. The antenna ground circuit was provided by six, 40-foot ground-wire radials extending from the antenna base.

3-4. A block diagram of the receiving-station equipment is shown in figure 2. This equipment included two receiving channels, three receiving antennas, a reference transmitter and its antenna, timing circuits, gating circuits, and display circuits which provided simultaneous amplitude information on the two receiving channels and a display of the instantaneous phase difference between the r-f signals received at two antennas.

3-5. The three receiving antennas used were 36-foot, aluminum, vertical whip antennas placed on the ground at the apexes of a right triangle. The length of each of the perpendicular sides of this triangle was 132 feet and these sides were oriented to provide antenna pairs, either perpendicular or parallel to the great circle course through Trinidad, Colorado, where the field unit was situated. The ground circuit for each receiving antenna was provided by six, 40-foot ground-wire radials.

3-6. A fourth vertical whip antenna was placed equally distant from the three receiving antennas for the purpose of radiating a reference signal. Provision was made for adjusting this reference signal so that its frequency differed from the frequency of the transmitted field-equipment signal by precisely 100 cps. The reference signal was provided by combining the outputs of a one-megacycle crystal-controlled oscillator and a high-frequency crystal oscillator identical to those used in the field equipment. The one-megacycle local oscillator, mixer, and power amplifier which provided the reference signal were situated at the antenna. The high-frequency oscillator was situated in the laboratory and its output was delivered to the mixer by means of a coaxial cable.

3-7. Each of the two receiving channels included a Hammerlund SP600JX high-frequency communication receiver modified by provision of common external crystal-local-oscillators. As indicated in figure 2, the 455-kc i-f output of each receiver was delivered to an external i-f amplifier and detector.

3-8. The output of each detector consisted of the pulse-modulated 100-cps difference frequency generated by mixing the reference-transmitter signal and the field-equipment signal at the antenna associated with each channel. These detector outputs were then delivered to separate gating circuits where a synchronizing-gate pulse of variable width gated through selected signal modes for observation and comparison.

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3-9. As indicated in block diagram figure 2, basic timing for the generation of the synchronizing-gate pulse was provided by a 400-cps tuning fork oscillator and a 360-degree, continuous phase shifter. The 400-cps tuning-fork oscillator was identical to the 400-cps tuning-fork oscillator used in the field equipment to control the prf of the field equipment pulses. This permitted precise synchronization of the prf of the field-equipment pulses and the prf of the synchronizing gates, while the 360-degree phase shifter provided for synchronization of the phase of the field-equipment pulses and the phase of the synchronizing-gate pulse.

3-10. Clipping the output of the tuning-fork oscillator and differentiating the resulting square wave provided the trigger for a one-shot multivibrator whose pulse output could be varied in duration from 50 to 1500 microseconds. The output of this multivibrator controlled the gating circuit of each receiver channel. The detector output of each receiver channel and the output of the synchronizing-gate pulse generator were presented simultaneously on the cathode-ray oscilloscope by means of a dual-trace preamplifier.

3-11. The part of the received signal permitted to pass through the gating circuits by the synchronizing-gate pulse was delivered to band-pass filter and amplifier circuits whose net output bandwidth was 8 cps, centered at 100 cps. The effect of these narrow-band filters was to remove the pulse modulation imposed by the gating circuits on the detector output and to produce a continuous 100-cps signal.

3-12. The output of each filter circuit was applied directly to the horizontal-deflection amplifier of a cathode-ray oscilloscope and through a 90-degree phase shifter to the vertical-deflection amplifier. When properly adjusted, a circular pattern was produced on each oscilloscope, the diameter of which was proportional to the signal amplitude.

3-13. Squaring and amplifying the output of the second receiver channel and then differentiating the resultant produced a trigger for actuating a monostable multivibrator at each zero crossing of the 100-cps wave. (The circuits used to produce this result are included in the block labeled, "brightening-pulse generator".) The pulses provided by this multivibrator were used to introduce a brightened dot on the circular sweep of both cathode-ray oscilloscopes. The position of this brightened dot on the circular pattern remained fixed at 12 o'clock on the second channel cathode-ray oscilloscope since the circular sweep on this display was produced by the same 100-cps signal which produced the brightened pulse. However, on the first receiver channel cathode-ray oscilloscope, the brightened dot produced by the zero-crossing pulse occupied an angular position on the circular sweep which was a measure of the phase difference between the two 100-cps signals. This, in turn, was the same as the phase difference between the r-f signals received at the two antennas. Differences in phase response of the r-f portions of the two channels were cancelled because of the common reference signal used in both channels.

4-0. RESULTS OF FIELD TESTS.

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4-1. The propagation field test was carried out during the period 5 July 1955 to 8 July 1955, inclusive, over the 802-mile path from Trinidad, Colorado, to Los Angeles, California. Of the three frequency channels available for the test, only the lower two, 7.473 mc and 12.575 mc, were usable under the propagation conditions prevailing during the test period. Four pulse lengths (80, 160, 320, and 750 microseconds) and cw transmissions were used at different times throughout the test. This was done to observe the effects of various degrees of resolution of multipath modes and of multipath echoes within a given mode provided by different pulse widths. Table I presents a brief summary of the field-test transmission log, together with remarks on the received signal where applicable.

TABLE I

SUMMARY OF TRANSMISSION LOG

Date	Time	Frequency (mc)	Type of Transmission	Remarks
5 July 55	1645-1910	7.473	Pulse	Multiple modes present
	2115 - 2355	7.473	Pulse and cw	
6 July 55	0800-0925	7.473	Pulse and cw	Multiple modes present
	1130-1225	12.575	Pulse and cw	Single hop E region
	1400-1515	12.575	Pulse	Single hop E region
	1520-1545	7.473	Pulse	Very weak signal
	1550-1655	12.575	Pulse	Single hop E region
7 July 55	0800-1200	12.575	Pulse	Multiple modes present until 0900
	1550-1837	12.575	Pulse and cw	Single hop E region
	1845-2043	7.473	Pulse and cw	
8 July 55	0615-0648	12.575	Pulse	No signal observable
	0648-0715	7.473	Pulse and cw	Single hop E region
	0715-0905	12.575	Pulse	Multiple modes present

4-2. When either the two longer pulse lengths, or cw transmission was used with both E and F modes present, the interference between the modes made it practically impossible to obtain a consistent reading even over periods of a few seconds. When the shorter pulse lengths were used, several multipath echoes could frequently be observed within the expected E and F modes. These multipath echoes could usually be resolved by using the shortest transmitted pulse length (80 microseconds). In this case, it was possible to obtain consistent readings on any given echo, but on occasions, when even the short echoes overlapped, the phase readings on the cathode-ray oscilloscope again became erratic and in fact, varied from one edge of the echo to the other.

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4-3. With a single E-region echo present on 12.575 mc, the azimuthal angle-of-arrival varied through an angle of about 2 degrees, while the vertical angle-of-arrival at times varied by more than 20 degrees. The direction of arrival of the F-region echo at the 12.575-mc frequency varied within approximately the same limits as the E-region echo, but was much more erratic in its behavior than the E-region echo.

5-0. CONCLUSIONS. Results of these experiments indicate that even in the practically ideal case where pulses were transmitted continuously and accurate manual selection of the desired mode-of-arrival was possible at the receiver, the phase stability of the signal received at two antennas would not permit angle-of-arrival measurements of a sufficiently high order of accuracy and stability to satisfy the navigation-system requirements as proposed.

6-0. ALTERNATE SYSTEMS. Current investigations are directed toward determining the feasibility of alternate systems. These include systems using direction-finding techniques on signals radiated from existing high-power, low and medium-frequency transmitters, and systems operating in the high-frequency band employing range and, or, range-difference measurements for localization of the aircraft.

7-0. MAN-HOURS. During the period from 13 June 1955 to 10 July 1955, [REDACTED] man-hours of effort were devoted to System No. 2.

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